A New Sampling Strategy to Estimate the Mean Phosphate Content of Fields

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The intensive animal husbandry in the Netherlands produces a large surplus of manure. The application rates of manure exceed the phosphorus crop uptake. The soil gradually becomes saturated, and ultimately the phosphate leaches to the groundwater and surface water. To prevent further degradation of the environment, the application of manure is regulated by law at present. For fields with low phosphate levels the allowed quantity of manure leads to a further decrease of the phosphate reserves and of the crop yield. Higher application rates will be permitted for these fields under a new regulation.

A new sampling strategy, intended for nationwide application, is designed to estimate the mean phosphate content of fields and to test hypotheses statistically. The field to be sampled, is stratified geographically. The strata are of equal area and are as compact as possible. This stratification is done by non-hierarchical classification of the points of a discretization grid, using the x- and y-coordinates as classification variables, and the within-group sum of squares as minimization-criterion. Computing time could be reduced significantly by transferring points near stratum boundaries only. From each stratum one sample is selected by simple random sampling. These samples are bulked into one composite sample. In laboratory this composite sample is mixed, sub-sampled and analyzed.

The composite sample mean is an unbiased estimator of the field mean because the area of the strata is equal. To predict the sampling variance, the variogram have been estimated for 16 fields differing in landuse, parent material and phosphate level. The semivariance was related to the phosphate level, therefore we also estimated the pooled relative variogram. This variogram was used to predict the sampling variance for various levels of the sample size (20 to 50), field area (1 to 10 ha) and phosphate levels (30 to 60mg P_2O_5 per 100 gram or dm^3). For 40 sample points (standard sample size of the current strategy) the predicted sampling variance was smaller than the variance of the measurement error if the composite sample is analyzed only once. These variances are more or less equal if the composite is sub-sampled and analyzed twice.

The stratification leads to a good spread of the sample points over the field. This can also be achieved by systematic grid sampling but a drawback of this sampling design is that the sample size is random. The increase in precision due to stratification depends on the variogram (nugget-sill ratio and range). Also, given a variogram, the increase in precision generally increases with the sample size. For 40 sample points the variance ratio (sampling variance of Simple Random Sampling divided by sampling variance of Stratified Simple Random Sampling) varied from 1.2 to 2.5 for the 16 fields.

The cost model consists of three components: i) fieldwork cost; ii) laboratory cost; iii) equipment cost. The costs of fieldwork and equipment are related to the time needed for fieldwork. Time components are amongst others i) time to digitize the field; ii) computing time (stratification and random selection); iii) time to walk to sample points, and iv) sampling time. We assumed that to digitize the field and to locate the random points a Global Positioning System is used. The predicted once-only cost of digitizing and stratification varied from US$ 10 (1 ha) to US$ 50. The predicted recurrent cost of sampling and laboratory analysis varied from US$ 35 (1 ha, 5 points) to US$ 65 (10 ha, 50 points).